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Misleading Postevent Information and Memory for Events: Arguments and Evidence Against Memory Impairment Hypotheses

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The claim that a person's memory for an event may be altered by information encountered after the event has been influential in shaping current conceptions of memory. The basis for the claim is a series of studies showing that subjects who are given false or misleading information about a previously witnessed event perform more poorly on tests of memory for the event than subjects who are not misled. In this article we argue that the available evidence does not imply that misleading postevent information impairs memory for the original event, because the procedure used in previous studies is inappropriate for assessing effects of misleading information on memory. We then introduce a more appropriate procedure and report six experiments using this procedure. We conclude from the results that misleading postevent information has no effect on memory for the original event. We then review several recent studies that seem to contradict this conclusion, showing that the studies do not pose problems for our position. Finally, we discuss the implications of our conclusions for broader issues concerning memory.

The claim that a person's memory for an event may be altered by information encountered after the event (e.g., Loftus, 1979a, 1979b; Loftus & Loftus, 1980) has rekindled interest in basic questions about forgetting and has contributed to the growing concern about the potential unreliability of eyewitness testimony. More generally, the claim has been influential in shaping current conceptions of memory, particularly the view that memory representations are highly mutable and often contain distortions or even gross inaccuracies.

The basis for the claim is a series of studies conducted by Elizabeth Loftus and her colleagues (e.g., Loftus, 1977; Loftus, 1979a; Loftus & Greene, 1980; Loftus, Miller, & Burns, 1978). In a typical study, subjects first view a sequence of slides depicting an event such as a traffic accident. The subjects then receive additional information about the event, such as a written narrative account of what took place. For subjects in the *misled* condition, the narrative provides misleading information about a detail from the slide sequence. For example, a stop sign that appeared in the slides might be described in the narrative as a yield sign. For subjects in

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Table 1
Design of a Typical Postevent Information Experiment

Condition	Slides	Narrative	Test
Control	Stop	—	Stop versus Yield
Misled	Stop	Yield	Stop versus Yield

the *control* condition, the narrative provides no specific information about the critical detail. Table 1 summarizes the design.

After presentation of the narrative, subjects in both conditions are given a two-alternative forced-choice recognition test on what they saw in the slides. For the question about the critical detail (e.g., What type of sign was at the intersection?), the choices are the item that was in the slides (stop sign), and the item presented to misled subjects as misleading postevent information (yield sign).

The consistent finding is that misled subjects perform more poorly than control subjects on the test question about the critical item. Loftus and her colleagues have interpreted this misleading information effect to mean that misleading information "overwrites" or replaces the original information in the representation of the event, so that the original information is irrevocably lost from memory (e.g., Loftus, 1979a, 1979b, 1981; Loftus & Loftus, 1980; Loftus et al., 1978). Recently, several researchers (e.g., Bekerian & Bowers, 1983; Christiaansen & Ochalek, 1983) have questioned this interpretation, contending that the original information is not lost from memory, but is merely rendered inaccessible (i.e., nonretrievable).

In this article we suggest that misleading postevent information has no effect on memory for the original event. In other words, we argue that misleading information neither erases original information nor renders it inaccessible. In developing this argument, we first show that the basic finding of poorer misled than control performance does not imply that misleading information causes any sort of memory impairment. In fact, we argue that the procedure used in previous studies is unsuited for assessing effects of misleading information on memory. We then introduce a more appropriate procedure, present several experiments using this procedure, and conclude from the results that presentation of misleading postevent information has no effect on subjects' ability to remember what they originally saw. Next, we review several recent postevent information studies that seem to conflict with our conclusion, showing that these studies do not in fact pose problems for our position. Finally, we discuss the implications of our conclusions for broader issues concerning the workings of memory.

The Misleading Information Effect Reconsidered

In this section we show that the misleading information effect does not imply that misleading postevent information impairs memory for the original event. In making this point we will continue to use the stop sign/yield sign experiment as an example. However, the argument we develop is a general one that applies to all of the studies demonstrating misleading information effects (e.g., Loftus, 1975, 1977; Loftus & Palmer, 1974).

Consider first how the subjects in the control group will perform on the recognition test. At the time of the test some of the control subjects will remember seeing a stop sign (i.e., they will be able to access information specifying that the sign was a stop sign). These subjects should uniformly choose the correct response on the test. However, some control subjects will not remember the sign, either because they never encoded it, or because they forgot it between the initial presentation and the test.[1] (Of course, any forgetting by control subjects can have nothing to do with the presentation of misleading information, because these subjects are not exposed to misleading information.) On the stop sign versus yield sign test, the control subjects who do not remember the stop sign

[1] When we say that a subject cannot remember, or has forgotten, some piece of information, we simply mean that under the conditions of the test the subject cannot access the information in memory. It is irrelevant for our purposes whether the information that cannot be accessed has been lost from memory or is in memory but inaccessible. Similarly, when we say that a subject remembers some piece of information, we mean that under the conditions of the test the subject can access the information in memory.

Table 2
Expected Test Performance for Control and Misled Conditions in a Hypothetical Situation

Memory state for original information	Percentage of subjects in memory state	Expected performance on test
Control condition		
Remember	40%	100% correct
Don't remember	60%	50% correct
Total percentage correct		70% (40% + 30%)
Misled condition		
Remember	40%	100% correct
Don't remember	60%	25% correct
Total percentage correct		55% (40% + 15%)
Misled condition		
Remember	40%	75% correct
Don't remember	60%	25% correct
Total percentage correct		45% (30% + 15%)

will have to guess and therefore should be correct 50% of the time.[2]

Imagine a hypothetical situation in which 40% of the control subjects remember the stop sign and 60% do not. As shown in the upper portion of Table 2, the overall percent correct for the control group in this situation should be 40% (all of the subjects who remember the stop sign) plus 30% (half of the subjects who do not remember the sign), or 70%.

The usual interpretation for the poorer performance in the misled condition than in the control condition is that the percentage of subjects who remember the original information is lower in the misled condition. In our example, this interpretation would say that fewer than 40% of the misled subjects remembered the stop sign (because the misleading information "erased" the stop sign representation, or rendered it inaccessible). It is certainly true that if fewer misled subjects than control subjects remember the original information, performance will be worse in the misled condition. However, even if the percentage of subjects who remember the original information is the same in both conditions, we still expect poorer performance in the misled condition.

Assume that the misleading information has no effect on the misled subjects' ability to remember what they originally saw, so that in the misled condition, as in the control condition, 40% of the subjects remember the stop sign and 60% do not. In addition, assume for the moment that the misled subjects who remember the stop sign will give the correct response on the test. Consider, though, the misled subjects who do not remember the stop sign. Will these subjects, like the corresponding control subjects, simply guess and so be correct 50% of the time? Clearly not. Subjects who do not remember what they saw—stop sign—but do remember what they read in the narrative—yield sign—will presumably choose the yield sign on the test and so will be systematically incorrect. Of course, subjects who remember neither the original information nor the misleading information will guess on the test. However, as long as any subjects who do not remember the stop sign do remember the yield sign, the overall level of performance for misled subjects who do not remember the original information will be lower than the corresponding control level of 50%. Consequently, performance will be worse in the misled condition than in the control condition.

The middle portion of Table 2 shows an example in which half of the misled subjects who do not remember the stop sign do remember the yield sign. In this example, the overall performance level for the misled condition is 55%, considerably below the control level of 70%.

Thus, even if misleading information has no effect on the subjects' ability to remember what they originally saw, performance will be worse in the misled condition than in the control condition. The reason is that mislead-

[2] We are assuming here that proper counterbalancing procedures have been used, so that overall performance will be about 50% correct for subjects who do not remember the sign even if there is a general bias toward choosing one of the signs—for example, the *stop sign*—among subjects who do not remember what they saw. However, the argument we will develop applies even if counterbalancing procedures have not been used and performance for subjects who do not remember the original sign is systematically above or below 50%.

ing information will bias the responses of subjects who, for reasons unrelated to the presentation of misleading information, fail to remember what they originally saw. All that is required for the misleading information effect to occur is that (a) some subjects fail to remember the original information for reasons unrelated to the presentation of misleading information (this will be the case whenever control performance is below ceiling) and (b) some misled subjects who fail to remember the original information do remember the misleading information.

There is also another factor that may contribute to poorer misled than control performance even if misleading information has no effect on subjects' ability to remember the original information. We initially assumed that all of the misled subjects who remembered the original information would choose the correct response on the test. However, some subjects who remember both the original information (stop sign) and the misleading information (yield sign) may choose the latter on the test. For example, a subject who thinks that the slides showed a stop sign, but also thinks that the narrative described the sign as a yield sign might reason that the experimenter who prepared the narrative must have known what was in the slides, and hence that the sign must have been a yield sign. Thus, misled subjects who remember the original information may be less than 100% correct on the test.

The lower portion of Table 2 revises the middle example to include this second potential source of misled–control differences not attributable to effects of misleading information on memory for the original event. It is assumed that half of the subjects who remember the original information also remember the misleading information and that half of the subjects who remember both pieces of information choose the incorrect alternative on the test. Under these assumptions the expected performance in the misled condition is 45% correct, much lower than the 70% expected for the control condition.

The finding of poorer performance in misled conditions than in control conditions does not, then, imply that presentation of misleading information impairs subjects' ability to remember what they originally saw.[3] The procedure used in previous studies is simply unsuited for determining whether misleading information impairs memory for the original event. In the following section we describe a modified procedure that permits clearer inferences about the effects of misleading information on memory.

The Modified Test Procedure

The modified procedure is the same as the original procedure except for one crucial change in the recognition test phase. However, we will use a new example to explain the new procedure. Suppose that subjects first view a sequence of slides, one of which shows a man holding a hammer (the critical item). The subjects then read a narrative describing the event depicted in the slides. In the control condition the narrative gives no specific information about the critical item. In the misled condition the narrative refers to the critical item as a screwdriver. After reading the narrative, the subjects are given a recognition test on what they saw in the slides.

The original test procedure requires subjects to choose between hammer, the originally seen item, and screwdriver, the item presented to the misled subjects as misleading information. In the modified test procedure, the misleading information (screwdriver) is not included as an option on the test. As shown in Table 3, subjects are asked instead to choose between the original item (hammer) and a new item (wrench). Unlike the original test procedure, the modified test procedure can be used to determine whether misleading information affects subjects' memory for what they initially saw. If misleading information impairs subjects' ability to remember the original information, then misled subjects should perform more poorly than control subjects. However, if misleading information does not affect memory for the original information, then the control and misled conditions should not differ.

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[3] In making this point, we have for simplicity assumed two discrete memory states (i.e., "remembered" or "not remembered") for original or misleading information. However, the arguments we developed (and those we make subsequently) are unaltered if we assume instead that subjects can have partial memory for original or misleading information.

Table 3
The Original Test Procedure and the Modified Test Procedure

Condition	Slides	Narrative	Original test	Modified test
Control	Hammer	—	Hammer versus Screwdriver	Hammer versus Wrench
Misled	Hammer	Screwdriver	Hammer versus Screwdriver	Hammer versus Wrench

Consider once again the hypothetical situation in which 40% of the subjects in both the control and misled conditions remember the original information (hammer) at the time of the test, and 60% do not. In the control condition all of the subjects who remember the original information should give the correct response on the modified test. The subjects who do not remember what they saw will have to guess, so that half should be correct. Thus, as shown in the top half of Table 4, the expected control performance is 40% + 30%, or 70%.

Consider now the subjects in the misled condition. Misled subjects who remember the original information should, like the corresponding control subjects, uniformly be correct on the modified test. The choices on the test are hammer and wrench; screwdriver is not an option. Thus, subjects who remember the original information—hammer—should choose the correct response on the test, whether or not they also remember the misleading information screwdriver.

Misled subjects who do not remember the original information should also perform like the corresponding control subjects. On a hammer versus wrench test, misled subjects who do not remember hammer must guess whether or not they remember the misleading information screwdriver. Thus, half of these subjects should be correct on the test. As shown in Table 4, in a situation where 40% of the misled subjects remember the original information and 60% do not, the expected performance is 40% + 30%, or 70%, the same as in the corresponding control condition.

In our implementation of the modified procedure the three versions of a critical item (e.g., hammer, wrench, screwdriver) are chosen so that they are all approximately equal in similarity to one another. For example, the similarity of screwdriver to hammer is approximately the same as the similarity of screwdriver to wrench. Thus, a misled subject who does not remember the original information (hammer) but does remember the misleading information (screwdriver) should not be biased toward either of the test alternatives (hammer or wrench). In addition, complete counterbalancing is used. For example, when screwdriver is the misleading information and the test is hammer versus wrench, the correct answer (i.e., the originally seen item) is hammer for some subjects and wrench for others.

In Experiments 1–6 we use the modified test procedure to evaluate the claim that misleading information impairs subjects' ability to remember originally seen material.

Experiments 1–6

Experiments 1–6 differ only in minor details and are in essence six replications of a single experiment. Hence, we report all six experiments together. In each experiment, subjects saw a sequence of slides, read a postevent narrative, and took a written rec-

Table 4
Expected Control and Misled Performance With the Modified Test Procedure in a Hypothetical Situation

Memory state for original information	Percentage of subjects in memory state	Expected performance on test
Control condition		
Remember	40%	100% correct
Don't remember	60%	50% correct
Total percentage correct		70% (40% + 30%)
Misled condition		
Remember	40%	100% correct
Don't remember	60%	50% correct
Total percentage correct		70% (40% + 30%)

ognition test on what they saw in the slides. The slide sequence contained four critical items that were used to make a within-subjects misled–control manipulation. For each subject the narrative gave misleading information about two of the items, and no information about the other two. Thus, for each subject there were two misled items and two control items.

In each experiment two groups of subjects were tested. Subjects in the *original test* group were tested with the original test procedure to ensure that we could replicate the misleading information effect obtained in previous studies. Subjects in the *modified test* group were tested with the modified test procedure.

Method

Experiment 1

We first describe the method of Experiment 1 and then detail the changes made in Experiments 2–6.

Subjects. Subjects were 120 undergraduate students at Johns Hopkins University and Towson State University. Sixty subjects were randomly assigned to each of two groups: the original test group and the modified test group.

Stimuli. The slide sequence was a series of 79 color slides depicting an incident in which a maintenance man enters an office, repairs a chair, finds and steals $20 and a calculator, and leaves. The slide sequence included four critical slides, each showing one of the four critical items. For each critical slide three different versions were prepared. The critical items and the three versions of each were as follows: a coffee jar (Folgers, Maxwell House, Nescafe), a magazine (Glamour, Vogue, Mademoiselle), a soft drink can (Coca-Cola, Seven-Up, Sunkist Orange Soda), and a tool (hammer, wrench, screwdriver). For each critical item each version was presented to one-third of the subjects. For example, one-third of the subjects saw a hammer, one-third saw a wrench, and one-third saw a screwdriver.

The narrative was a 735-word detailed description of the incident shown in the slides. For each subject the narrative presented misleading information about two of the critical items (misled items) and neutral information about the other two (control items). The assignment of critical items to misled and control conditions was counterbalanced across subjects. Specifically, each version of each critical item served as a control item for half of the subjects to whom it was presented and a misled item for the other half. For example, half of the subjects who saw a hammer in the slides received a narrative referring to it simply as a tool (control condition), and the other half received a narrative referring to it as a wrench or screwdriver (misled condition). Further, for each version of each critical item, the two alternative versions were used equally often as misleading information. For example, for subjects who saw a hammer and were then misled about this item, half received screwdriver as the misleading information, and half received wrench as the misleading information. Except for variations in reference to the critical items, the narrative was the same for all subjects.

Procedure. Subjects were tested in groups of 4 to 20. As a rationale for the presentation of the slides and narrative, subjects were told that the experiment concerned intuitions about memory. The subjects were informed that they would see a slide sequence depicting an event, and would then read a written description of the event. The task, they were instructed, was to judge whether memory for the event would generally be better with the visual or the verbal mode of presentation. The subjects were told to pay careful attention to both the slides and the narrative.

The subjects then (a) viewed the slide sequence at a presentation rate of 4 s per slide, (b) performed a 10-min unrelated filler task, (c) read the narrative once at their own pace, (d) performed a second 10-min filler task, (e) answered two questions concerning their intuitions about memory and mode of presentation, and (f) completed a 36-item forced choice recognition test. The subjects were told to answer the questions solely on the basis of what they saw in the slides. The instructions indicated that for each question one of the two alternatives was correct.

All test questions were sentences with a missing word and two alternatives. For example, for the tool critical item, the test question was "The man slid the calculator beneath a _____ in his tool box." Thirty-two of the 36 questions were fillers, and these were the same for all subjects. The remaining 4 questions consisted of 1 question for each of the four critical items. The four critical questions were the same for all subjects, except for variations in the response alternatives. The alternatives were dictated by the test condition (original test or modified test), the version of the item that appeared in the slides, and the version presented as misleading information. For example, for a subject in the modified test condition who saw a hammer in the slides and was presented with screwdriver as misleading information, the test alternatives were hammer and wrench. Across the experiment, the same test alternatives were used for both control and misled critical item questions. Thus, the control and misled conditions differed only in whether the subject received misleading information about an item. For each critical test question, the response alternatives were presented in one order (e.g., hammer, wrench) to half of the subjects, and in the other order (wrench, hammer) to the remaining half.

Experiments 2–6

Experiments 2–6 were identical to Experiment 1, with the following exceptions: (a) in Experiments 2–6 the slides were presented for 5 s each; (b) in Experiments 3–6 subjects read the narrative twice, and the filler task between the narrative and the test was eliminated; and (c) the number of filler items on the recognition test was 6 in Experiments 3 and 5, 16 in Experiment 4, and 32 in Experiment 6.

The number of subjects in the original and modified test groups also varied across experiments. For the modified test condition, the number of subjects was 84 in

Experiments 2 and 6, and 72 in Experiments 3–5. For the original test condition, the number of subjects was 84 in Experiment 2, 48 in Experiments 3 and 5, 72 in Experiment 4, and 36 in Experiment 6. (original test groups were included only to demonstrate that we could obtain a misleading information effect when we used the procedure that was used in previous studies. Large groups were not needed to obtain this effect, and so in some experiments we tested fewer subjects in the original test group than in the modified test group.)

Results

Tables 5 and 6 present for each of the six experiments the mean percent correct for control and misled items in the original test and modified test conditions. The minor procedural variations among the six experiments had no discernible effect on the pattern of results in either the original or modified test condition. Hence, we will treat the experiments as six replications of a single study.

The results for the original test condition replicated the findings of previous studies. Averaging across the six experiments, the mean recognition test performance was 37% correct for misled items and 72% correct for control items. In each individual experiment, a large misled–control difference was obtained.

Several *t* tests were performed with subjects as a random effect and with items as a random effect. (For the items analyses, the number of correct responses in the misled condition and the control condition was tabulated for each of the 12 individual versions of critical items: hammer, wrench, screwdriver, and so forth.) In the subjects analyses, the misled–control difference was reliable at the .001 level for each of the six experiments and when the data were collapsed across experiments ($ts \geq 4.0$). In the items analyses, the misled–control difference was reliable at or beyond the .01 level in each experiment and when the data were collapsed across experiments ($ts \geq 3.3$).

Table 5
Percent Correct Recognition in Experiments 1–6 for Misled and Control Items in the Original Test Condition

Experiment	Misled	Control	Difference
1	40	67	27
2	40	72	32
3	35	70	35
4	42	75	33
5	30	75	45
6	36	75	39
Mean	37	72	35

Table 6
Percent Correct Recognition in Experiments 1–6 for Misled and Control Items in the Modified Test Condition

Experiment	Misled	Control	Difference
1	66	71	5
2	71	77	6
3	77	73	−4
4	74	81	7
5	70	68	−2
6	71	77	6
Mean	72	75	3

In the modified test condition, the pattern of results was quite different. Averaging across the six experiments, recognition test performance was 72% correct in the misled condition and 75% correct in the control condition. In the individual experiments, misled–control differences were consistently very small, ranging from −4% (4% better performance in the misled than in the control condition) to +7%. In subjects analyses and items analyses for the individual experiments, the misled–control difference never approached significance ($ts \leq 1.6$, $ps > .1$). The outcome was the same when the data were collapsed across experiments: $t(443) = 1.4$, $p > .1$, for the subjects analysis and $t(11) = 1.7$, $p > .1$, for the items analysis. Thus, with the modified test, performance in the misled condition did not differ from performance in the control condition.

We conclude from these results that misleading postevent information does not impair subjects' ability to remember what they originally saw. In other words, misleading information neither erases the original information nor renders it inaccessible.

Discussion

How does our conclusion accord with the results of previous studies? We have already shown that the misleading information effect obtained with the original test procedure does not imply that misleading information

impairs memory for originally seen material. In the following sections we discuss several recent postevent information studies that appear to conflict with the conclusion we have drawn, showing that because of logical or methodological problems, these studies provide no basis for inferences concerning effects of misleading information on memory and hence pose no problems for our position.

The Weinberg, Wadsworth, and Baron (1983) Study

Weinberg et al. used a recognition test similar to our modified test, but obtained a different result. Subjects in their study viewed a sequence of slides, one of which showed a yellow yield sign. Postevent information describing the sign as a yield sign (control condition) or a stop sign (misled condition) was then presented. The test consisted of a forced choice between a slide showing a yellow yield sign and a slide showing a red yield sign. Thus, as in our modified test, subjects chose between the originally seen item (yellow yield sign) and a new item (red yield sign). However, in contrast to our findings of no misled–control difference, Weinberg et al. found poorer performance in the misled condition (60% correct) than in the control condition (78% correct).

The Weinberg et al. results probably reflect not a memory impairment caused by misleading information, but rather an unfortunate choice of items coupled with a failure to counterbalance. Consider the subjects who at the time of the test did not remember what they originally saw. In the control condition these subjects had to guess; the postevent information (yield sign) provided no basis for choosing a particular test alternative. In the misled condition, however, the situation was different. Some misled subjects who did not remember the original information presumably remembered the misleading information (stop sign). Faced with a yellow yield sign versus red yield sign test, it seems likely that many of these subjects would choose the alternative most similar to a stop sign; that is, the red yield sign. Thus, among subjects who did not remember the original information, the misleading information may have created a bias toward selection of the incorrect test alternative. This response bias is simply a milder form of the bias in the original test procedure, where the misleading information is identical, and not merely similar, to the incorrect test alternative.

A bias of this sort will, of course, lead to poorer performance in the misled condition than in the control condition, even if the misleading information has no effect on subjects' ability to remember what they originally saw. Thus, the Weinberg et al. results can readily be interpreted without assuming that the misleading postevent information impaired subjects' memory for the original event.

Second-Guess Studies

In three experiments reported by Loftus (1979a), misled subjects were given a three-alternative forced choice in which the alternatives were the originally seen item (e.g., stop sign), the item presented as misleading information (e.g., yield sign), and a new item (e.g., no-parking sign). The subjects were asked to indicate their first choice and, on the assumption that this choice was wrong, their second guess. The purpose of the second guess was to determine whether any of the subjects who selected the misleading information on the first choice nevertheless had some memory for the original information.

In all three experiments second-guess performance among subjects who initially chose the misleading information was no better than chance. Loftus concluded from these results that none of the subjects who initially selected the misleading information remembered the original information and hence that presentation of misleading information caused original information to be forgotten.

A major problem with this reasoning concerns the leap from the first conclusion—that none of the subjects who initially chose the misleading information remembered the original information—to the second conclusion—that presentation of misleading information caused forgetting of the original information. The second conclusion follows from the first only if it can be assumed that some of the subjects who chose the misleading information on the first choice would have remembered the original information if they had not been misled. However, this "would-

have-remembered" assumption is not justified. Loftus and others have considered the assumption to be a self-evident consequence of the finding of poorer misled than control performance (in studies using the original test procedure). As we have shown, however, this finding does not necessarily mean that any misled subjects who selected the misleading information would have remembered the original information had they not been misled. A misled–control difference could be due entirely to biasing effects of the misleading information on the responses of subjects who, for reasons unrelated to the presentation of this information, did not remember the original information.

To justify the would-have-remembered assumption in a second-guess study, one would have to show that the misled–control difference on the first choice was too large to be accounted for entirely in terms of this response bias and therefore that some misled subjects who otherwise would have remembered the original information must have chosen the misleading information. However, no such demonstration was made in Loftus's second-guess studies. In fact, Loftus did not demonstrate any misled–control difference, because she did not report control-condition data. Thus, in the second-guess studies the set of subjects who initially chose the misleading information may have consisted entirely of subjects who, for reasons unrelated to the presentation of misleading information, did not remember the originally seen item. Consequently, chance performance among these subjects on the second guess does not imply that misleading information caused forgetting of the original information.

The failure to justify the would-have-remembered assumption takes a particularly dramatic form in one of the second-guess studies Loftus (1979a) reports. Subjects saw a slide sequence that included a traffic sign (e.g., a stop sign). One week later, the subjects were given misleading information about the sign (e.g., they were told it was a yield sign). A stop sign versus yield sign versus no-parking sign test was then given, and subjects were asked to indicate both first and second choices. Subjects who selected the misleading information on the first choice performed at chance on the second choice.

The problem with this study is that even before the misleading information was introduced, 1 week after presentation of the slides, all of the subjects may have forgotten the critical sign. In an experiment using the same slide sequence, Loftus et al. (1978, Experiment 3) found that control subjects tested 2 days after presentation of the slides performed at chance on recognition of the critical sign. If all of the subjects in the second-guess study had forgotten the critical sign before presentation of the misleading information, any subsequent test—including a second-choice test—would have shown no memory for the originally seen sign. Obviously, such results would not imply that the failure to remember the original sign had anything to do with presentation of misleading information.

The other two second-guess studies described by Loftus (1979a) have serious response bias problems. We will discuss only one of these studies because both have the same flaw. Subjects saw a slide sequence that included a man reading a book. Half of the subjects saw a yellow book, and the other half saw a blue book. Misleading information was then presented—subjects who saw a yellow book were told that it was blue, and subjects who saw a blue book were told that it was yellow. Finally, subjects were asked to indicate their first and second choices on a blue/green/yellow test. Of the subjects who initially chose the misleading information, only 23% chose correctly on the second choice; 77% selected the incorrect color (green). Because second-guess performance was not above chance, Loftus concluded that none of the subjects who initially chose the misleading color remembered the original color and therefore that the misleading color information caused forgetting of the original color.

As in the other second-guess studies, the second part of Loftus's conclusion—that the misleading color caused forgetting of the original color—is unwarranted because of the failure to justify the would-have-remembered assumption. However, in this study the first part of the conclusion—that none of the subjects who initially chose the misleading color remembered the original color—is also unwarranted, because of a response bias problem. Consider, for example, the subjects

who saw a yellow book, were told it was blue, and selected blue as their first choice on the blue/green/yellow test. On the second guess these subjects must choose between green (incorrect) and yellow (correct). Any subjects who remember the original color yellow would probably choose correctly on the second choice. What, though, of the subjects who do not remember the original color? Some of these subjects presumably chose blue on the first choice because they remembered the misleading information. We would expect these subjects to show a strong tendency to choose the incorrect color green on the second choice: of the two choices (green and yellow) it is the closer to blue, the color they remember. Hence, subjects who do not remember the original color are likely to perform well below 50% correct. The fact that second-guess performance in Loftus's experiment was well below chance—23% correct—clearly indicates that response biases of this sort were operating.

When subjects who do not remember the original information are biased toward the incorrect response on the second guess, overall second-guess performance may be at or below chance even if some of the subjects who initially selected the misleading information remember the original information. Thus, it cannot properly be concluded from the second-guess data that none of the subjects who initially chose the misleading color remembered the original color, or that presentation of misleading color information caused forgetting of the original color.

Warning Studies

A "warning" procedure has been used to ask whether misleading information causes original information to be lost from memory, or instead to be rendered inaccessible. Warning studies typically involve three conditions: a control condition, a misled condition, and a misled/warned condition. The control and misled conditions are the same as in a typical study using the original test procedure. The misled/warned condition is identical to the misled condition except that subjects are warned after presentation of misleading information, but before the test, that some (unspecified) details in the postevent information may have been inaccurate.

The rationale for the warning procedure is as follows: If misleading information merely renders the original information inaccessible, then the warning may somehow allow subjects to regain access to this information. A finding of better performance in the misled/warned condition than in the misled condition would imply that the proportion of subjects who could remember (i.e., access) the original information was higher in the former condition, and hence that the warning allowed some misled/warned subjects to recover original information rendered inaccessible by the misleading information. Equal performance in misled/warned and control conditions would imply that the proportion of subjects who remembered the original information was the same in both conditions, and hence that misleading information caused no loss of original information from memory.

This rationale is invalid because it assumes incorrectly that one can determine whether the proportion of subjects who remembered the original information in two conditions of a warning study was the same or different simply by comparing overall performance for the two conditions. The problems with this assumption become apparent when we consider the expected performance in each condition for subjects who remember the original information and subjects who do not (see Table 7).

Consider first the subjects who remember (i.e., can access) the original information. In the control condition these subjects should

Table 7
Expected Performance for Subjects Who Do and Do Not Remember the Original Information

Memory for original information	Condition		
	Control	Misled	Misled/Warned
Remember	Perfect	Perfect or less than perfect	Perfect or less than perfect
Don't remember	Chance	Below chance	Above chance, chance, or below chance

show perfect performance. In the misled condition their performance may be perfect (if all misled subjects who remember the original information choose the correct alternative on the test) or less than perfect (if some misled subjects who remember both the original and the misleading information opt for the latter on the test).

In the misled/warned condition the performance of subjects who remember the original information may also be perfect or less than perfect. The warning should reduce any tendency of subjects who remember both the original and misleading information to choose the latter on the test. However, some subjects who remember both pieces of information might still respond incorrectly if, for example, they were unable to remember which item came from the slides and which came from the postevent information.

Consider now the subjects who do not remember the original information. In the control condition these subjects should perform at chance. In the misled condition performance should be below chance, because subjects who remember the misleading information but not the original information should systematically choose the misleading information on the test.

In the misled/warned condition the situation is more complex. Subjects who remember neither the original information nor the misleading information should perform at chance. Consider, though, the subjects who do not remember the original information but do remember the misleading information. Some of these subjects, because they have no recollection of the original information to contradict the misleading information, may opt to accept the misleading information in spite of the warning. These subjects will be uniformly incorrect. However, some subjects who remember the misleading information but not the original information may, because of the warning, reject the misleading information as possibly false. By rejecting an incorrect alternative, these subjects will perform above chance on the test. Depending on the relative proportions of subjects who accept the misleading information in spite of the warning and subjects who reject the misleading information, overall performance among misled/warned subjects who do not remember the original information may be above chance, at chance, or below chance.

The consequence of these considerations is that overall performance data for misled/warned, misled, and control conditions are uninformative with regard to effects of misleading information on memory for originally seen material. Whether or not misleading information causes original information to be lost from memory, and/or to become inaccessible, performance in the misled/warned condition may be worse than, equal to, or even better than performance in the control condition. Similarly, regardless of the effects of the misleading information, misled/warned performance may be better than or equal to misled performance.

This point can be made clear by examining the results of the available warning studies. We will consider only the two studies in which a warning was issued after presentation of misleading postevent information (Greene, Flynn & Loftus, 1982; Christiaansen & Ochalek, 1983). (Experiments in which a warning was given *before* presentation of misleading information—for example, Dodd & Bradshaw, 1980—have generally not been considered relevant for determining whether misleading information affects memory for the original event, because a prior warning could improve test performance by leading subjects to ignore the misleading information when it is initially presented.)

Christiaansen and Ochalek emphasize the results of analyses focusing on a subset of their data, and we will discuss these results later. However, we will first consider the findings obtained when all of the data are taken into account. In both the Christiaansen & Ochalek study and the Greene et al. study, performance was better for misled/warned conditions than for misled conditions, although the difference was significant in only some comparisons. In the Christiaansen & Ochalek study, misled/warned performance was worse than control performance. (In the Greene et al. experiment, no control condition was included.)

The finding of better misled/warned than misled performance does not show that the warning allowed some misled/warned subjects to access original information rendered inaccessible by the misleading information, be-

cause several alternative interpretations of the result can be offered. To give just one example, the warning may have caused some misled/warned subjects who remembered the misleading information but not the original information to avoid the misleading information on the test, leading to better performance in the misled/warned condition than in the misled condition among subjects who did not remember the original information. The finding of poorer misled/warned than control performance is similarly uninformative.

Let us now consider the findings Christiaansen and Ochalek emphasize in their report. Subjects in their experiments viewed a slide sequence including four critical items. An initial multiple-choice test containing questions about the critical items was then presented. Two days later subjects read a narrative that contained misleading information (misled and misled/warned conditions) or neutral information (control condition) about all four critical items. After reading the narrative, misled/warned subjects were warned that a few unspecified details in the narrative were incorrect. All subjects were then given a final multiple-choice test that included questions about the four critical items.

The data Christiaansen and Ochalek focus on are the final-test responses for those critical-item questions that the subject answered correctly on the initial test (i.e., the test given before presentation of misleading information). When only initially accurate items were considered, performance was as good in the misled/warned condition as in the control condition.

Christiaansen and Ochalek argue from this result that misleading information renders original information inaccessible, but causes no loss of original information from memory. In fact, however, no clear conclusions can be drawn. Restricting the analysis of final-test data to those items that were answered correctly on the initial test should exclude some but not all of the subjects who, at the time of the final test, did not remember the original information. The procedure could not exclude subjects who did not remember the original information at the time of the initial test but selected the correct response by guessing, or subjects who forgot the original information between the initial test and the final test 2 days later. It is especially clear in Christiaansen and Ochalek's Experiment 2 that restricting the analysis to initially accurate items did not exclude all of the subjects who did not remember the original information; final-test performance on initially accurate items in the control condition was only 36% correct.

Because the final-test results for the initially accurate items included responses both from subjects who remembered the original information and from subjects who did not remember the original information, these results are subject to the interpretive problems discussed earlier. Thus, the finding of equal performance in the misled/warned and control conditions does not imply that the proportion of subjects who remembered the original information was the same in both conditions. As discussed earlier, the warning may cause some misled/warned subjects who do not remember the original information to avoid the misleading information on the test and so to perform better than the chance performance expected for the corresponding control subjects. Consequently, overall misled/warned performance could be as good as overall control performance even if fewer misled/warned than control subjects remembered the original information.

Christiaansen and Ochalek attempt to counter this sort of objection, by presenting data to suggest that misled/warned subjects who failed to remember the original information did not avoid the misleading information on the test. Given these data, they argue, the finding of equal misled/warned and control performance does imply that misleading information caused no loss of information from memory. This argument is incorrect, because Christiaansen and Ochalek's assumptions do not explain the finding of equal misled/warned and control performance, but lead instead to a prediction of poorer misled/warned than control performance. If misled/warned subjects who fail to remember the original information do not avoid the misleading information on the test, these subjects will perform more poorly than the corresponding control subjects. In particular, misled/warned subjects who remember only the misleading information will choose the misleading information on the test and

so will by systematically incorrect. Consequently, overall performance should be worse in the misled/warned condition even if the proportion of subjects who remember the original information is the same in this condition as in the control condition.

Thus, if we accept Christiaansen and Ochalek's assertion that misled/warned subjects who failed to remember the original information did not avoid the misleading information on the test, their results are anomalous. On the other hand, if we reject this assertion, the results are ambiguous. In either case the data do not allow inferences about effects of misleading postevent information on memory for the original event.

The Bekerian and Bowers (1983) Study

Like Christiaansen and Ochalek, Bekerian and Bowers contend that presentation of misleading information does not erase original information, but merely renders it inaccessible. They argue as follows: In Loftus's studies, the recognition test items are presented in random order and not in the order in which the queried information occurred in the original slide sequence. Thus, the retrieval environment does not closely match the original encoding environment. The misleading information effect may occur because subjects are unable to access the original information effectively under these conditions and instead retrieve the postevent information. If the test reinstated the original encoding environment more fully, subjects might be able to access the original information effectively and misled subjects might perform as well as subjects who have not been misled.

To test this hypothesis, Bekerian and Bowers conducted an experiment in which subjects viewed a sequence of 24 slides that included a traffic sign (e.g., a stop sign) as the critical item. Some subjects received consistent postevent information (e.g., stop sign), and some received misleading information (e.g., yield sign). In the test phase subjects were shown 15 pairs of slides and asked to indicate for each pair which slide was present in the original sequence. Some subjects received the test items in random order (random test condition), whereas others received the items in the order in which they occurred in the original slide sequence (sequential test condition). The critical test item required subjects to choose between a stop sign and a yield sign.

In the random test condition performance on the critical test item was better for subjects given consistent postevent information (94% correct) than for subjects given misleading information (60% correct). However, in the sequential test condition, performance did not differ for subjects given consistent information (85% correct) and misleading information (87% correct). Bekerian and Bowers conclude from these results that presentation of misleading information did not cause the original information to be irrevocably lost, but merely rendered it inaccessible under the conditions of the random test.

This conclusion is not valid because Bekerian and Bowers' assumptions do not explain their results. In particular, the assumption that a sequential test allows the original information to be accessed as readily in the misled condition as in the consistent condition does not lead to a prediction of no difference between the two conditions on the sequential test. Bekerian and Bowers used the original test procedure; for the critical test question the alternatives were the originally seen item and the item presented to misled subjects as misleading information. As we have pointed out, when the original test procedure is used, poorer misled than control performance is expected even if misleading information has no effect on the subjects' ability to remember (i.e., access) the original information. This prediction applies to sequential as well as random tests. Hence, the Bekerian and Bowers sequential test results are anomalous. These results are all the more surprising in that the misled condition was compared not with a control condition in which the postevent information said nothing specific about the critical item, but rather with a consistent condition in which the postevent information gave a specific accurate description of the critical item. Thus, the misled subjects at best had a single source of reliable information about the critical item, whereas the consistent subjects had two different sources that could be relied upon.

Because the Bekerian and Bowers results are anomalous, we attempted to replicate

these results with our stimulus materials. We used the same design and procedure as in the original test conditions of our other experiments, except in the test phase. Thus, we compared misled and control conditions instead of misled and consistent conditions.

In our test phase we made Bekerian and Bowers' manipulation for reinstating the encoding context even stronger. In the random test condition, eight pairs of test slides were presented in random order. In the sequential test condition, the entire original slide sequence was presented at test in the original order. The only difference between the original presentation and the test was that for eight of the positions in the sequence a pair of test slides was presented. Each test pair consisted of the slide from the original sequence and a distractor in which a detail had been changed. The eight test pairs—four concerning critical items and four fillers—were the same in the random and sequential test conditions. As in the Bekerian and Bowers study, the original test procedure was used. For each critical item, the alternatives were the original slide and a slide in which the critical item had been replaced with the item given to misled subjects as misleading postevent information. Eighty-four subjects were tested in each of the two test conditions.

As expected, our results were quite different from those of Bekerian and Bowers. In the random test condition, performance on critical-item questions was 41% correct for misled items and 70% correct for control items. In the sequential test condition the results were almost identical, 37% correct for misled items and 68% correct for control items. The misled–control difference was reliable, $F(1, 166) = 60.9$, $p < .01$, but no other effects approached significance (Fs < 1). It is obvious from these results that the random versus sequential test manipulation had no effect on performance in either the misled condition or the control condition.

We suggest that our results and not Bekerian and Bowers' reflect the true state of affairs. Each mean in our study represents 168 data points, whereas in the Bekerian and Bowers study only 16–30 data points contributed to each mean. More important, our results are interpretable, whereas Bekerian and Bowers' findings are anomalous, regardless of what assumptions are made about effects of misleading information on memory for the original event. We conclude, therefore, that the Bekerian and Bowers results do not imply that for the misled subjects the original information was inaccessible under random test conditions and was made accessible by the use of a sequential test.

In summary, the findings of postevent information studies have consistently been taken to mean that misleading information impairs memory for the original event, either by erasing stored information about the event or by rendering this information inaccessible. We have shown, however, that because of logical problems with the procedures used, or methodological problems with the particular experiments reported, the results of previous studies provide no clear basis for conclusions about effects of misleading information on memory for originally seen material.

In contrast to previous findings, our modified test results can be brought to bear on questions concerning effects of misleading information on memory. These results strongly suggest that misleading information has no effect on a person's ability to remember the original event. Of course, our results cannot rule out the possibility that under some conditions misleading postevent information does affect memory for originally seen material. For example, our experiments, like virtually all previous postevent information studies, used a recognition test procedure. Hence, it remains an open question whether misleading information affects a person's ability to *recall* original information.

The recall–recognition issue is interesting in light of previous research on retroactive interference (RI). Traditional RI studies, like misleading postevent information experiments, examine the effects of subsequent information on memory for material presented earlier. It is not a foregone conclusion that the traditional RI studies, which for the most part involve paired-associate word lists, are relevant to situations involving memory for events. Nevertheless, it is interesting to note that RI is consistently obtained with recall procedures, but is typically weak or absent when recognition tests are used (for

reviews, see, for example, Crowder, 1976; Postman & Underwood, 1973).

General Discussion

We have presented arguments and evidence against the claim that misleading postevent information impairs memory for the original event. However, studies of postevent information have also led to a more general and seemingly less controversial claim—the claim that information about an event obtained from various sources is integrated in memory into a single representation of the event (e.g., Loftus, 1979a; Loftus et al., 1978). According to this claim, a person who attends a baseball game and later reads a newspaper story about the game constructs a single representation that incorporates both the information obtained through direct observation and the information from the story.

What is the evidence bearing on the integration claim? The misleading information effect obtained with the original test procedure demonstrates that postevent information can influence *responses* to questions about an event. However, interpretation of this finding requires virtually no specific assumptions about the nature of the relevant memory representations or how these representations are accessed and used. The same is true of results showing that subjects' responses may be influenced by postevent information that does not directly contradict information from the original event (e.g. Loftus, 1975), and studies (e.g., Loftus, 1975, 1977) demonstrating that subjects may give test responses that represent a compromise between original information and postevent information (e.g., a response of *blue-green* when *blue* is the original information and *green* is the postevent information). These results simply illustrate the obvious point that original information, postevent information, or both, can be used as a basis for answering questions. The person who has both seen and read about a baseball game may answer questions about the game on the basis of his or her direct observations at the game, the newspaper story, or both, regardless of the precise nature of the game representation(s) or how they are retrieved.

Data from other experimental paradigms (e.g., Bransford & Franks, 1971; Carmichael, Hogan, & Walter, 1932) are similarly uninformative. For example, the Carmichael et al. finding that verbal labels influence reproduction of line drawings has sometimes been taken as support for the integration view (e.g., Loftus, 1979a). However, like the results from the postevent information studies, this finding does not imply anything very specific about the representation or retrieval of information from the verbal labels or the drawings. A subject who remembers the label *eyeglasses* but recalls little about the appearance of the drawing so labeled will probably produce a drawing that looks more like eyeglasses than the original drawing, whether or not information provided by the label has in any sense been integrated in memory with information from the drawing.

What sorts of data would, then, support or disconfirm the integration claim? Consideration of this question leads quickly to the realization that what is meant by integration is not at all clear. One might suggest that the integration claim simply asserts that information from various sources is stored together in memory. Although this answer may be satisfying at an intuitive level, it loses much of its appeal when we ask, What does "stored together in memory" mean? How, for instance, do items that are stored together behave differently from items that are stored separately? Unless we can answer these questions, we have succeeded only in exchanging one vague notion for another.

This is not to say that no specific interpretation of the integration claim can be conceived. On the contrary, the claim is so vague that several quite different interpretations can be imagined. For example, one possible interpretation is that information from various sources collectively acts as a single unit for purposes of retrieval, such that information from one source cannot be retrieved selectively. An alternative interpretation is that only a single version of each episode making up the event is maintained in memory (e.g., Loftus & Loftus, 1980). According to this view, if the baseball fan's observations at the game disagreed with the newspaper article on a particular point, only one of the two versions would be maintained in memory. A third interpretation is that stored propositions are not tagged with information about the

source from which they were obtained. On this view the baseball fan who remembers some episode from the game will have no knowledge of whether the stored information about the episode came from direct observation, the newspaper story, or both.

It is not our intention in this article to propose or evaluate specific interpretations of the integration claim. The interpretations we have mentioned are merely illustrative and are still insufficiently explicit. Our point is simply that the integration claim, as it typically appears in the memory literature, is so vague and ambiguous as to be virtually meaningless. Until the claim is made more specific, we cannot determine whether it is reasonable, what its implications are, or what sorts of data would serve to support or disconfirm it. If we are to progress in our understanding of human memory, we must relinquish vague claims of this sort in favor of specific proposals.

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